*Combining* (1), (2), *and* (3) *in one formula, we have*

$$m = 2{\cdot}5\ (\log t - 0{\cdot}97\sqrt{d}) + \text{const.} \quad . \quad . \quad . \quad . \quad (4)$$

*which may be considered as replacing the approximate empirical formula given in the* "*Monthly Notices*" *for March*, 1891, *vol. li. p.* 284.

*Royal Observatory, Greenwich:*
1892 *January* 8.

---

## *On the Observations for Coincidence of the Collimators through the Cube of the Transit Circle at the Royal Observatory, Greenwich* (II). By H. H. Turner, M.A., B.Sc.

In a former paper (*M.N.* vol. xlvi. p. 329) I referred to the fact that when observations for coincidence of the collimators at the Royal Observatory were made by viewing the South Collimator with the North through eight holes of sector form cut in the central cube of the transit circle, the readings were found to differ systematically from those obtained when the view was unobstructed; and I detailed a series of simple experiments which seemed to show that this phenomenon was purely optical. This conclusion has been confirmed by an interesting and elaborate series of experiments by Dr. Wislicenus at Strasburg. (*Ast. Nach.* No. 3067). He states his chief conclusions as follows:—

1. The systematic differences found at Greenwich are purely of an optical nature, and can be obviated by making the hole in cube circular and larger than the object-glasses of the collimators.

2. If the object-glass of a telescope be obscured by concentric discs or rings quite symmetrically, or by symmetrical screens of other forms, such as the radial bars at Greenwich, not only is the character of the focal image altered, but it *may* be displaced laterally.

With regard to the excellent though somewhat obvious suggestion in (1), it may be remarked that there are practical difficulties in the way of adopting it in the case of the Greenwich transit circle; but the point should not be lost sight of in designing a new instrument.

With regard to conclusion (2), Dr. Wislicenus lays some stress on the word *may*. He is inclined to attribute such lateral displacements to residual chromatic and spherical aberrations, which make the actual focus of an object-glass somewhat indefinite. Instead of a bright point we get in fact a short line of light along the optical axis, the brightest point of which is selected for focussing. Cutting off some of the rays, however symmetrically, will cause a different point of this line to be selected, and for all but central pencils we shall thus get a paral-

lactic effect. The suggestion is of value, and it will be seen that paragraph ($\iota$) in what follows seems to distinctly support it.

The subject having thus attracted attention elsewhere, and having possibly an important bearing (as Dr. Wislicenus remarks) on heliometer and other observations where object-glasses are sometimes screened, I have thought it advisable to communicate to the Society some further notes which I put together some years ago, but which were laid aside at the time because of the negative character of some of the conclusions, which may be summarised as follows:—

(I.) The systematic difference under discussion, after remaining constant for several years, began to change, and numerically doubled itself. At present there are signs of its returning towards the smaller values.

(II.) No cause can be assigned with certainty for this change. Either the figures of the object-glasses have slightly changed, or, possibly, adopting the above suggestion of Dr. Wislicenus, the eccentricity of the pencil has been changed, and the parallactic effect consequently increased.

(III.) The effect which should be traced on stellar observations is found to be extravagantly too large, pointing to some other disturbing cause.

I proceed now to give the notes nearly as they were drawn up in 1888:—

($\alpha$) "Experiments on the effect of the limitation of aperture of the collimators when observations are taken through the central cube of the transit circle having led to the suspicion that the object-glasses of the collimators might be defective, they have been examined by Mr. Simms, who has reported that they are excellent." (*R.A.S. Council Report*, Royal Observatory, Greenwich, 1887, February; *M.N*, vol. xlvii. p. 149). We are thus not dealing with any defect such as a good optician eliminates in constructing object-glasses.

($\beta$) It is probable that any form of screen would produce some effect on the reading for coincidence. A few experiments were made, not on the two collimators, but with the transit-circle telescope on each of them, using a screen to cover half the object-glass, as follows:—

*T.C. on North Collimator.*

| Date. | Observer. | Whole O.G. | Excess of Reading of T.C. micrometer with Screen covering Upper half. | Lower half. | E. half. | W. half. |
|---|---|---|---|---|---|---|
| | | | r | r | r | r |
| 1886. Apr. 20 | H. T. | ... | ·000 | −·009 | +·006 | +·047 |
| 1887. Feb. 29 | H. T. | ... | ·000 | +·004 | −·005 | +·154 |
| 29 | H. T. | ... | ·000 | −·013 | −·024 | +·108 |
| Mar. 3 | H. T. | −·004 | ·000 | +·012 | +·010 | +·082 |
| 3 | H. T. | +·003 | ·000 | −·004 | −·010 | +·035 |

*T.C. on South Collimator.*

| Date. | Observer. | Whole O.G. | Excess of Reading of T.C. micrometer with Screen covering Upper half. | Lower half. | E. half. | W. half. |
|---|---|---|---|---|---|---|
| 1886. | | | r | r | r | r |
| Apr. 20 | H. T. | ... | ·000 | ·000 | −·013 | +·014 |
| 1887. | | | | | | |
| Feb. 29 | H. T. | ... | ·000 | −·014 | −·025 | +·037 |
| 29 | L. | ... | ·000 | −·021 | −·029 | +·036 |
| Mar. 3 | H. T. | +·012 | ·000 | −·023 | −·018 | +·019 |
| 3 | H. T. | −·001 | ·000 | −·018 | −·004 | +·011 |

1 rev. of the micrometer = 14″·78.

(γ) The discordance between readings for coincidence of collimators through the cube and with unobstructed view has undergone a curious change in the course of years. The following is a complete list of the mean annual values to date:—

| | | | | | |
|---|---|---|---|---|---|
| 1871 | 0″·58 | 1878 | 0″·53 | 1885 | 0″·99 |
| 1872 | ·56 | 1879 | ·56 | 1886 | 1·14 |
| 1873 | ·56 | 1880 | ·61 | 1887 | 1·19 |
| 1874 | ·56 | 1881 | ·80 | 1888 | 1·02 |
| 1875 | ·53 | 1882 | ·73 | 1889 | 1·21 |
| 1876 | ·53 | 1883 | ·87 | 1890 | 1·21 |
| 1877 | ·61 | 1884 | ·77 | 1891 | 0·87 |

The value was thus sensibly constant for ten years, but has since either been continuously changing, or has suffered two more or less abrupt changes about 1881 and 1885. The following paragraphs give the results of the examination of various hypotheses which might account for this change or changes.

(δ) *Change of Observer.*—It is possible that personality may have some influence on the result. Below are two sets of results collected according to separate observers:—

| 1877–1879. | No. of Obs. | Discordance. | 1882–1887. | No. of Obs. | Discordance. |
|---|---|---|---|---|---|
| Lynn | 22 | 0″·58 | Lewis | 38 | 1″·07 |
| Criswick | 11 | ·46 | Hollis | 61 | 0·85 |
| Downing | 27 | ·65 | Downing | 76 | 0·95 |
| Thackeray | 16 | ·48 | Thackeray | 13 | 1·23 |

Two observers are common to the two sets, and the changes are apparently independent of the observer.

(ε) *Introduction of the Reversion Prism Eyepiece.*—The observations in earlier years had not been reduced in the first instance, and attention was therefore drawn only to the change in 1885. It was at once suspected that this might be due to the introduction of the reversion prism eyepiece, and observations to

compare this with the ordinary eyepiece previously in use were made as follows:—

On 1888 March 1 I took the following readings of N. Coll. on S. Coll. through the cube:—

| R.P. Eyepiece. $r$ | R.P. Eyepiece. $l$ | Mean. | Ordinary Eyepiece. | Diff. in rev. | Diff. in arc. |
|---|---|---|---|---|---|
| $r$ | $r$ | $r$ | $r$ | $r$ | $''$ |
| ·685 | ·704 | ·695 | ·696. | + ·001 | +0·02 |
| ·668 | ·701 | ·685 | ·690 | + ·005 | +0·12 |
| ·665 | ·697 | ·681 | ·691 | + ·010 | +0·24 |

Each number in columns 1 and 2 is the mean of three, and in columns 3 and 4 of six observations.

On 1888 March 12 readings were also taken by all the four regular observers with both eyepieces, and both through the cube and with instrument raised, as follows:—

| Observer. | Excess of reading through Cube. R.P. Eyepiece. | Excess of reading through Cube. Ordinary Eyepiece. | Diff. R.P.−O. |
|---|---|---|---|
| | $''$ | $''$ | $''$ |
| H. T. | +1·11 | +1·40 | −0·29 |
| A. D. | +0·87 | +0·90 | −0·03 |
| T. | +0 24 | +0·99 | −0·75 |
| L. | −0·22 | +0·31 | −0·53 |
| H. | +0·44 | +0·65 | −0·21 |
| Mean | +0·49 | +0·85 | −0·36 |

Thus the correct use of the R. P. eyepiece will certainly not explain an *increase* in the discordance.

($\zeta$) It was suspected, however, that the position of the prism in front of the aperture of the eye-lens might have some influence on the results. It had occasionally been found out of adjustment, being held only by a single screw, round which as a centre it was liable to be rotated. The limit of displacement which might be unnoticed by the observer is, on one side a position when enough light comes through the uncovered portion of the eye-lens to give a second image of the field of view (1); and on the other side a position where some phenomenon of total reflexion occurs and the field becomes quite dark (2). Between positions (1) and (2) is that of good adjustment, which we may call (3). On 1888 March 12 the following observations of N. Coll. on S. Coll. were taken with the prism in these three positions.

| Observer. | Reading of N. Coll. Micr. Position (1). | Reading of N. Coll. Micr. Position (3). | Reading of N. Coll. Micr. Position (2). |
|---|---|---|---|
| | $r$ | $r$ | $r$ |
| H. T. | ·664 | ·660 | ·645 |
| H. T. | ·665 | ·667 | ·634 |
| H. T. | ·663 | ·670 | ·636 |
| L. | ·618 | ·615 | ·605 |
| H. | ·616 | ·623 | ·596 |
| Mean | ·645 | ·647 | ·623 |

Thus if the prism is out of adjustment towards the position (1) the readings are not sensibly affected, but towards the position (2) the readings of N. Coll. micr. are spuriously diminished. Thus, as before, an *increase* in the discordance under examination cannot be explained by bad adjustment of the prism.

($\eta$) *Changes of position of the Collimators with reference to the Central Cube.*—The most important change in the mounting of the collimators was made early in 1882, when they were mounted on two pivoted stalks so that they could be turned aside to allow of a greater range of reflexion observations with the transit circle. An inspection of the annual results for the years immediately preceding and following 1882 shows that this change did not affect the discordance under discussion. There have been, however, slight changes in relative azimuth, and possibly slight lateral shiftings of the axis of one or all three telescopes. After the Y's of the transit circle telescope had been taken out and cleaned early in 1888, it was found that the telescope went back into a sensibly different position, closer to its western pier, towards which it is pressed by a spring. Small pieces of dirt had been accumulating for years on the western bearing, and the removal of these allowed of a slight lateral shift. This of course would alter the exact position of the interposed cube with reference to the collimator object-glasses.

Changes in relative azimuth, both periodic and secular, are known to occur, though their total amount is very small—probably less than a minute of arc; and it does not seem likely that changes of this magnitude would affect the results. But both these possible causes were considered.

($\theta$) *Lateral Shiftings.*—The wooden model of the cube was alternately placed in two positions separated by about $\frac{1}{2}$-inch in the E. & W. direction, and readings of the transit-circle micrometer were taken for coincidence with the N. Collimator on 1888 March 15.

| Observer. | No. of Obs. | Cube. East. | Cube. West. | E.–W. | E.–W. In arc. |
|---|---|---|---|---|---|
| | | $r$ | $r$ | $r$ | $''$ |
| H. T. | 10 | ·331 | ·348 | –·017 | –0·25 |
| H. T. | 10 | ·364 | ·372 | –·008 | –0·12 |
| H. T. | 10 | ·356 | ·361 | –·005 | –0·07 |
| H. | 10 | ·304 | ·340 | –·036 | –0·53 |
| H. | 10 | ·310 | ·352 | –·042 | –0·62 |
| Mean | | ·333 | ·355 | –·022 | –0·32 |

There seems to be, therefore, a small effect due to lateral shift; but half an inch is probably a much larger quantity than any which occurred in actual fact.

Under this head I may remark that observations are some-

times made through the cube with the transit-circle telescope pointing vertically upwards instead of vertically downwards. Any slight want of symmetry of the aperture with respect to the optical axis of the collimators might cause a difference between the two methods. Observations by Mr. Miskin on 1891 December 29 seem to show that there is no sensible difference. Mean readings of N. Coll. micr. as follows:

| | O.G. up. | O.G. down. |
|---|---|---|
| | r | |
| | ·566 | |
| | | r |
| | | ·568 |
| | ·603 | |
| | | ·600 |
| | ·581 | |
| Mean | ·583 | ·584 |

Each number being the mean of six readings.

(ι) *Changes of Azimuth.*—The wire system in each of the collimators consists of two pairs of wires at right angles, forming at their crossing a square whose side is about 85″. If the discordance under consideration vary with the position in the field of view (as would follow, for instance, from Dr. Wislicenus' suggestion), it should be different for bisections made with opposite sides of the squares, which is equivalent to changing the relative azimuth by 170″—a much larger quantity than could correspond to any secular change. The following comparisons were made on 1888 March 12:

| Observer. | No. of Obs. | Right of Square. | Left of Square. | Diff. | Diff. in arc. |
|---|---|---|---|---|---|
| | | r | r | r | ″ |
| H. T. | 10 | +0·094 | +0·083 | +0·011 | +0·26 |
| H. T. | 10 | +0·072 | +0·042 | +0·030 | +0·73 |
| H. T. | 10 | +0·074 | +0·045 | +0·029 | +0·70 |
| T. | 6 | +0·082 | +0·072 | +0·010 | +0·24 |
| H. T. | 10 | +0·057 | +0·058 | −0·001 | −0·02 |
| H. T. | 10 | +0·041 | +0·031 | +0·010 | +0·24 |
| Mean | | +0·070 | +0·055 | +0·015 | +0·36 |

From 1877 to 1882 the common azimuth of the collimators was nearly always less than 10″ from the meridian. At the end of 1882 the screws of the S. Coll. apparently got loose, and the deviation from the meridian became large and irregular. The screws were tightened on 1883 May 9. Since then the azimuth of the S. Collimator has gradually changed, as follows:

| | | | |
|---|---|---|---|
| $7''$ | at the end of | | 1883 |
| 22 | ,, | ,, | 1884 |
| 22 | ,, | ,, | 1885 |
| 26 | ,, | ,, | 1886 |
| 40 | ,, | ,, | 1887 |

On 1888 January 18 the object-glasses of the collimators were taken out and cleaned. On restoring them the azimuth of the S. Coll. was found to be reduced to $30''$.

It was

| | | | |
|---|---|---|---|
| $27''$ | at the end of | | 1888 |
| 24 | ,, | ,, | 1889 |
| 27 | ,, | ,, | 1890 |
| 20 | ,, | ,, | 1891 |

The removal of the object-glasses for repolishing in 1891 August did not affect the continuity of the results.

There were new wires inserted in

| N. Coll. | S. Coll. |
|---|---|
| on 1874, June 29 | 1874, Nov. 9 |
| 1881, Jan. 31 | 1882, Dec. 25 |
| 1884, June 16 | 1883, March 13 |

($\kappa$) *The Effect of the Discordance on Stellar Observations.*—An erroneous determination of collimation would involve erroneous level, azimuth, and clock errors. It is easy to show that an error of $c''$ in collimation ultimately affects the R.A.'s of stars by $\frac{c \sec}{15}$ tan $\frac{1}{2}$ N.P.D. Now the observations for collimation have been partially corrected for the discordance under consideration, adopting the numerical value deduced from observations in the early years. For various reasons this constant was not changed even when it was found that the mean annual value of the discordance had increased to nearly twice its original amount. Thus the R.A.'s of stars in the years subsequent to 1880 should be increased by $k$ tan $\frac{1}{2}$ N.P.D., where $k$ may be taken as $0^{s}\cdot008$ for 1881–1884, and $0^{s}\cdot020$ for 1885–1890. To test the reality of this correction, a comparison of the R.A.'s of stars deduced from observations above and below pole in the years 1877–1883 was made, and a similar comparison for the years 1885–6. The difference between the two series should require a correction readily deducible from the above theoretical expression, and tabulated in the fifth column of the following table. It will be seen that the observed differences are extravagantly larger than the theoretical, although of the same sign; and point to some other disturbing cause.

| Limits of N.P.D. | Mean Excess of R.A. above Pole. 1877–1883. | 1885–6. | Diff. | Theoretical difference. |
|---|---|---|---|---|
| ° ° | s | s | s | s |
| 1– 5 | +·555 | +·269 | +·286 | +·001 |
| 5–10 | −·047 | −·244 | +·197 | +·003 |
| 10–15 | −·139 | −·253 | +·114 | +·005 |
| 15–20 | +·264 | −·244 | +·508 | +·006 |
| 20–25 | +·005 | −·141 | +·146 | +·007 |
| 25–30 | −·001 | +·002 | −·003 | +·009 |
| 30–35 | +·026 | −·077 | +·103 | +·011 |
| 35–40 | +·023 | −·063 | +·086 | +·013 |
| 40–45 | +·005 | −·155 | +·160 | +·015 |
| 45–50 | −·019 | −·069 | +·050 | +·017 |

On the other hand, the reflexion observations seem to agree well with theory. These are discussed annually, as "Corrections to Adopted Level Errors," in the Greenwich volumes; and the weighted mean correction for the years 1882–3 is $-0''\cdot28$, while that for 1885–6 is $+0''\cdot19$, exceeding the former by $+0''\cdot47$. According to the formula given above, this quantity should be $+0''\cdot57$.

---

## *A New Photographic Photometer for determining Star Magnitudes.* By W. E. Wilson.

I would like to bring before the notice of the Society the design of an instrument which I think will be of use in stellar photography, and especially in determining photographic magnitude of stars.

The instrument consists of a photographic plate and holder ($6\frac{1}{2}$ in. × 1 in.), moving in a slide in the direction of its greatest length. A spiral spring tends to pull the holder to one end of the slide, and a simple electro-magnetic escapement each time the magnet is excited allows the spring to advance the plate and holder $\frac{1}{10}$ inch. The entire apparatus screws into the eye-end of a photographic telescope.

A star whose magnitude is to be determined is focussed close to the end of the photo plate, and an exposure of say $100^s$ given. The magnet is then excited for a moment by the current from a contact-maker, driven by a clock; the plate moves forward suddenly $\frac{1}{10}$ inch, and a second exposure is given, which lasts only $63^s$. Again the plate moves forward to give a third exposure of $39^s\cdot8$, and the exposures are thus continued in the above ratio until they are reduced to $1^s$. The telescope is then set on a standard star, such as *Polaris*. The holder is moved back to its original position, and *Polaris* is placed $\frac{1}{10}$ inch below